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Clinical Insights

The assessment, interpretation and implementation of lung ultrasound examinations in Heart Failure: Current evidence and gaps in knowledge

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ABSTRACT

Lung ultrasound (LUS) is a simple, fast and non-invasive tool for pulmonary congestion assessment with higher accuracy for the detection of acute heart failure (HF) compared to clinical examination and chest radiography. The integrated assessment with other ultrasound and echocardiographic parameters can lead to a better systemic and pulmonary congestion characterization. Additionally, the combination of echocardiographic and pulmonary features can identify patients at higher risk for adverse outcomes, potentially facilitating both acute and chronic HF management and prognostic stratification. However, the optimal utilization of LUS needs to be better defined both in terms of imaging method and B-line thresholds which may differ based on the clinical scenario and, potentially, the HF phenotype. Despite the extensive potential role of LUS in a wide range of HF scenarios, clinicians may be unaware of the correct technique and exam interpretation. Specifically, the interpretation of LUS findings is influenced by several factors, such as imaging protocol, type of ultrasound transducer, patient positioning, and presence of concomitant pulmonary diseases. The aim of this review is to provide a practical overview of LUS in patients with known or suspected HF with the goal of providing a practical guide for clinicians and nurses in various clinical settings.

1. Introduction

Pulmonary congestion is a common finding of volume overload or volume shift in heart failure (HF) and its detection is essential to facilitate timely therapy initiation or adjustment prior to frank decompensation requiring hospitalization. Traditionally, the most often utilized clinical evaluation methods have been assessment of patient symptoms, the physical examination, and chest radiography (CXR). However, these approaches are either insensitive or difficult to use at the patient's home or in the outpatient setting. Lung ultrasound (LUS) is a simple, fast and non-invasive point-of-care tool that enables the detection and quantification of pulmonary congestion and pleural effusions. LUS can also be used to differentiate between other common diseases which may overlap or mimic the HF syndrome (e.g. pneumonia, and pneumothorax) [1]. Incorporating LUS in the assessment of patients with acute dyspnea is an approach with higher accuracy for the detection of acute HF (AHF) compared to natriuretic peptides (NP), chest auscultation or chest X-rays. As a result, LUS may be considered to confirm the diagnosis of AHF according to the 2021 ESC HF Guidelines in conjunction with other diagnostic examinations [2].

LUS is indeed an indirect, quantifiable measure of lung congestion likely to be indifferent to its cause, providing rapid information regarding congestion status [3]. Due to the wide availability of ultrasound devices, congestion can theoretically be assessed in multiple settings ranging from outpatient settings, and emergency departments to inpatient settings, including intensive care units [4].

The goals of this review are to provide a practical approach on how to perform a LUS examination in patients with known or suspected HF,

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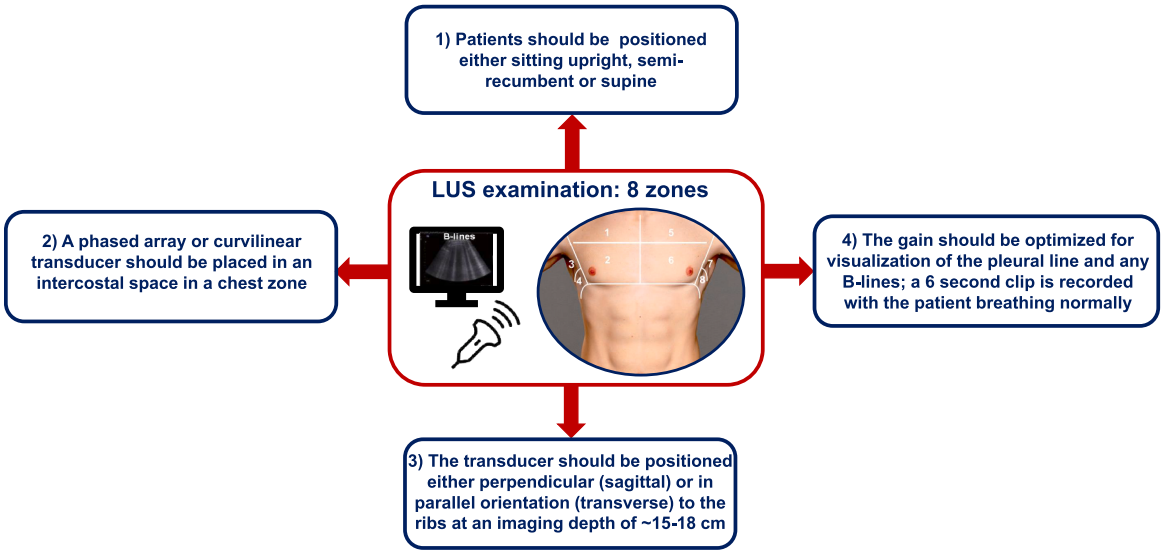
1) Patients should be positioned either sitting upright, semi-recumbent or supine
LUS examination: 8 zones
B-lines
2) A phased array or curvilinear transducer should be placed in an intercostal space in a chest zone
4) The gain should be optimized for visualization of the pleural line and any B-lines; a 6 second clip is recorded with the patient breathing normally
3) The transducer should be positioned either perpendicular (sagittal) or in parallel orientation (transverse) to the ribs at an imaging depth of ~15-18 cm
LUS: lung ultrasound

Fig. 1. Overview of optimal LUS examination: Patient positioning, ultrasound equipment, image acquisition protocol and LUS clip recording.

how to organize a training and clinical implementation program and finally how to address the clinical gaps in current knowledge.

2. How to perform a lung ultrasound examination?

2.1. Ultrasound equipment and image acquisition

LUS can be used for the identification and quantification of extravascular lung fluid in patients with known or suspected HF. LUS examinations can be performed with high-end ultrasound machines (such as those used for comprehensive echocardiograms), smaller, portable ultrasound systems and pocket-size ultrasound devices. Several LUS image acquisition protocols have been described, ranging from 4 to 28 areas of the chest or "zones", but the simplified 8-zone protocol is increasingly used both in the clinical setting and for research, and usually takes <5 min to perform (Fig. 1) [5]. So called 'B-lines' on LUS are reverberation artifacts that appear as vertical lines that arise from the pleural line and extend to the far-field of the ultrasound screen. B-lines can be observed in patients with HF, and are associated with extravascular lung fluid, but current images are not specific for cardiogenic pulmonary oedema. Ultrasound artefacts may occur in other conditions, such as non-cardiogenic pulmonary oedema, pulmonary infection or pulmonary interstitial fibrosis. Some specific sonographic characteristics together with patients' history and clinical examination, can improve diagnostic differentiation and the different aetiologies of B-lines [6]. For a LUS examination, patients are positioned either sitting upright, semi-recumbent or supine. Patients should preferably be imaged in the same position if serial examinations are being performed, as B-line number may be influenced by patient position, with higher B-line counts in supine position [7]. A phased array or curvilinear transducer is placed in an intercostal space in a chest zone either perpendicular (sagittal) or in parallel orientation (transverse) to the ribs at an imaging depth of ~15–18 cm. Once the gain settings are optimised for visualization of the pleural line and any B-lines, a 6 second clip is recorded with the patient breathing normally. Two previous studies compared the length of LUS clips in relation to the number of B-lines. A higher number of B-lines was identified on the 4- vs 2-second LUS clips ($P < 0.001$ for 4 zones, $P = 0.001$ for 8 zones), and on the 6- vs 4-second

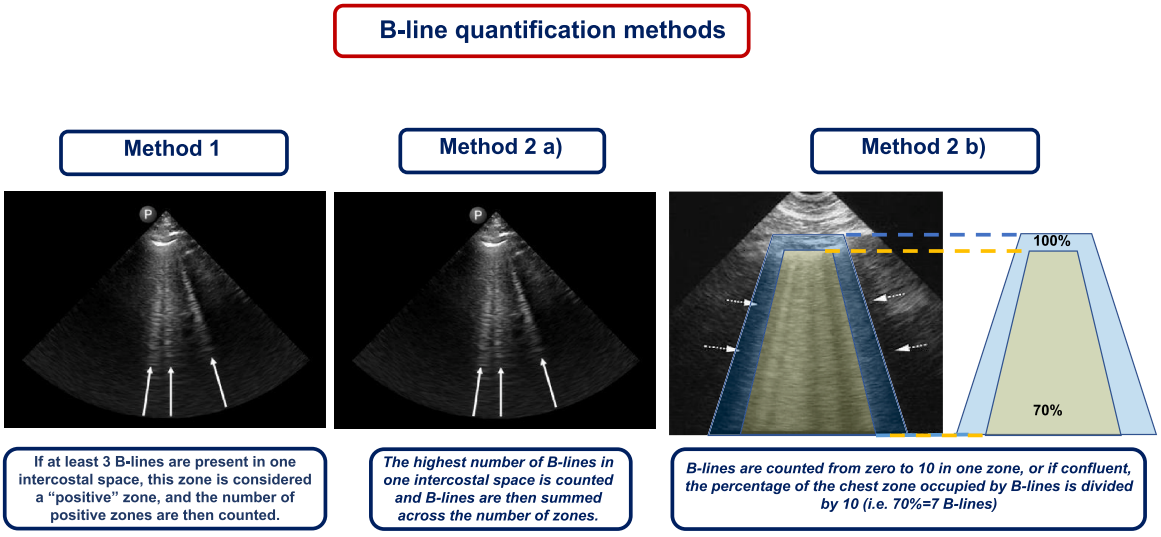
B-line quantification methods
Method 1
Method 2 a)
Method 2 b)
100%
70%
If at least 3 B-lines are present in one intercostal space, this zone is considered a "positive" zone, and the number of positive zones are then counted.
The highest number of B-lines in one intercostal space is counted and B-lines are then summed across the number of zones.
B-lines are counted from zero to 10 in one zone, or if confluent, the percentage of the chest zone occupied by B-lines is divided by 10 (i.e. 70%=7 B-lines)

Fig. 2. Different B-line quantification methods.

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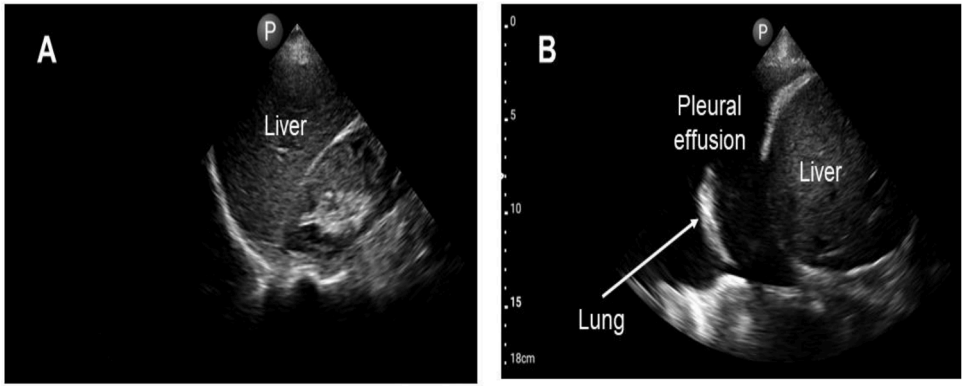

Fig. 3. Absence (3a) or presence (3b) of pleural effusions.

LUS clips ($P = 0.057$ for 4 zones, $P = 0.018$ for 8 zones) [8]. Evaluation time increased estimates by 1.2 (95 % CI 1–1.5) and 2.9 (95 % CI 2.7–3.9) B-lines for 4 and 7 s clips (reference was 2 s clips) [9]. Based on these data, a recent consensus statement suggested a 6 s-clip as reference time for images acquisition [5]. It should be noted that large pleural effusions may interfere with B-line identification and should be reported for the affected zones, if seen during the ultrasound examination.

2.2. How to quantify and interpret B-lines

There are several different approaches to quantifying B-lines. Broadly, these can be grouped into two categories: score or count based methods. *Method 1:* Score based methods consider a minimum number of B-lines in one intercostal space as a "positive" zone (typically at least 3 B-lines) and then adding up the number of positive zones [10]. *Method 2 a):* Count based methods are based on counting B-lines in one intercostal space in one zone and then summing B-lines across the number of zones [11,12]. *Method 2 b):* In addition, in the percentage-count method, B-lines are counted from zero to 10 in one zone, or if confluent, the percentage of the chest zone occupied by B-lines is divided by 10 (i.e. if about 70 % of the screen below the pleural line is occupied by B-lines, it would conventionally count as 7 B-lines, up to a maximum of 10 per zone) [13,14]. All the here described methods have demonstrated good intra- and inter-reader agreement [10,11]. (Fig. 2) LUS is more sensitive for the detection of pulmonary congestion than the clinical examination or CXR in patients with acute dyspnoea. In patients with dyspnoea presenting to the emergency department, a cut-off value of $\geq$3 B-lines in at least two zones per hemithorax (of 6–8 evaluated zones in total) identifies patients with acute HF with higher sensitivity (94–97 %) and specificity (96–97 %) than the physical examination and CXR (and NT-proBNP) (sensitivity 85 %, specificity 89–90 %) when using chart review by two physicians as the gold standard [10,15]. A high number of B-lines at the time of discharge from a hospitalisation for acute HF or in ambulatory patients with chronic HF identifies those at high risk of subsequent HF (re-) admissions or death in observational studies [11, 16]. Additional important methodological aspects of LUS image acquisition and B-line quantification are detailed in recent consensus documents [5]. Further research with direct comparison of imaging protocols and B-line quantification methods, may further clarify the diagnostic accuracy of these methods.

2.3. How to detect and quantify pleural effusions

Pleural effusions can be detected laterally on each hemithorax, by placing a curvilinear or phased array transducer in sagittal orientation in the posterior axillary line, at the level of the diaphragm in an intercostal space. Patients can remain in the same position as for B-line imaging. Pleural effusions appear as anechoic space cephalad to the diaphragm and can be semi-quantified by relating the collapsed lung to the diaphragm with a modified 4-point scoring system for each hemithorax (0=no pleural effusion, 4=massive pleural effusion) [17]. (Fig. 3) An alternative approach includes performing two linear measurements between the collapsed lung and the diaphragm as well as the height of the lateral chest wall. This method resulted in an intra-class correlation coefficient between the estimated and the thoracentesis obtained pleural effusion volume of 83 %. Similar to B-lines, the size of pleural effusions decreases with decongestive therapy in acute HF, however, the prognostic value of pleural effusions at the time of discharge from a hospitalization for AHF is less clear. In contrast to simple, anechoic fluid collections as a sign of volume overload in AHF, complex fluid collections in the pleural cavity should raise suspicion for alternative processes, e.g. empyema.

2.4. Training strategies and departmental implementation considerations

In spite of the growing evidence of the benefits of LUS in the diagnosis and management of HF, broad implementation has proved challenging within both inpatient and outpatient environments. In order to identify strategies that are most likely to accelerate adoption and competence, common barriers to implementation must first be acknowledged [18]. It is important to recognize that LUS implementation, like any complex health intervention, is greatly influenced by contextual factors that often vary by organization and region [19]. Therefore, it is recommended that doctors leading efforts to implement LUS within their clinical groups attempt to understand current barriers and facilitators unique to their practice prior to initiating implementation. This will facilitate the selection of implementation strategies that are most likely to be effective within the local practice.

For many years, lack of access to ultrasound equipment was cited as the dominant barrier to implementation of LUS for any indication. However, over the last few years, the growing selection of handheld devices with rapidly improving image quality at decreasing cost have mitigated this as a barrier, greatly improving access to clinicians [20]. Still, lack of training, time to perform LUS during clinical care, and lack of health system support for implementation persist as important barriers to LUS adoption among primary care providers, internists, cardiologists and emergency medicine clinicians for any diagnostic indication [21]. Practical strategies aimed at increasing implementation include:

Clinical pathways: Clinical pathways are practice-level interventions that aim to increase the adoption of evidenced-based practices in a manner that optimizes efficiency [22]. They do this by outlining disease-specific care plans that are aligned with available evidence, local workflows and culture. Given the high prevalence of HF, many internal medicine practices already have clinical pathways for HF. Evidenced informed LUS protocols can be added to existing HF pathways or implemented independently to operationalize and enhance adoption of LUS. Given the frequency of pulmonary comorbidities, such as interstitial lung disease, in patients with HF, clinicians must be trained to

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Table 1
Example of a lung ultrasound training program including didactic and practical lessons, knowledge and skills assessment.

Training component	Time invested or number of exams recommended	Description of training component
Didactic	2 h	Recommended Content (1–2 h): *Didactic 1* -Brief discussion of LUS physics and knobology (for clinicians without prior ultrasound training) -Discussion of B-lines, pleural effusion, consolidation, and pneumothora X*Didactic 2* -Review evidence for diagnosis of AHF using LUS in dyspneic patients, as well as LUS guided diuresis -Present clinical scenarios with LUS findings that emphasize the lack of specificity of B-lines for diagnosing cardiogenic pulmonary edema and caution against the common cognitive errors of mistaking all B-lines for cardiogenic pulmonary edema -Discusses evidence and rationale for the recommended exam imaging protocol -Demonstrate scanning technique
Supervised scanning	5 LUS exams	Supervised practice of: Appropriate machine settings -Appropriate exam technique -Saving and archiving images -Assessment of image quality -Image interpretation, clinical decision-making and generation of brief LUS exam report
Image and clinical decision-making Portfolio	25 images associated with actual patients	Images should a range of pathology including B-lines, pleural effusion, and hepatization. Images should be accompanied by the following documentation: 1) indication, 2) image interpretation and 3) clinical decision-making using LUS findings
Knowledge Assessment	25 questions	Clinical scenarios that assess for common cognitive errors in image quality, image interpretation and clinical decision-making using LUS findings
Quality assessment of independent use in clinical practice	10 exams	Evaluate image quality, image interpretation, clinical decision-making and quality of documentation in the electronic medical record

LUS: lung ultrasound, AHF: acute heart failure.

interpret LUS findings associated diseases other than HF to ensure appropriate clinical decision-making using LUS [23].

Task shifting: Evidence suggests that LUS implementation may be accelerated by initially focusing training efforts on a subset of physicians or other clinical staff (ie nurses, mid-level providers) that will then be charged with the task of performing LUS for the rest of their clinical group [24]. This approach may be feasible in some clinical setting and not others depending on local contextual factors. Internists in some countries including the US and UK will likely be comfortable with this workflow as it is similar to that of radiology performed imaging studies.

Integration of LUS images into the electronic medical record: Although many would argue image archiving and documentation of image interpretation and clinical decision making is important for any point-of-care ultrasound application, it is particularly important in LUS for HF so that B-lines can be trended and correlated with other measures of congestion and management decisions. Further, archiving and documentation of LUS exams and associated clinical decisions allows for monitoring of process and clinical outcomes which can improve quality in LUS training and implementation protocols as indicated.

Training considerations: Multiple studies have demonstrated that basic proficiency in identifying B-lines can be achieved with relatively brief training [25]. However, like any clinical skill, development from proficiency to mastery requires repeated use over time. Ideally, training should occur in a supervised clinical setting in which all three required skills – image acquisition, image interpretation and image integration into clinical management – can be practiced and evaluated. In addition to HF findings (i.e. B-lines and pleural effusions), other common pathologic findings (i.e. consolidation or septations) are taught at least briefly as these findings are likely to be encountered when examining patients for signs of HF [5]. (Table 1)

3. Pitfalls and gaps in evidence

3.1. Nonspecific nature of B-lines

B-lines are a nonspecific signs of cardiogenic pulmonary edema and can represent a wide range of disease processes. Their diagnostic significance must always be interpreted using additional clinical data. This is particularly relevant for diffuse interstitial syndrome, which may result from infections like pneumonia or from inflammatory conditions such as lung fibrosis. During the pandemic COVID-19 infection, subpleural condensation (identified by an irregular pleural line) was commonly observed. Because pulmonary infection and pulmonary edema due to acute HF often co-exist, determining the extent to which each diagnosis contributes to symptoms can be challenging. Furthermore, conditions like lung fibrosis or post-surgical inflammation leading to fibrosis can present with moderate to severe B-lines unrelated to fluid congestion, necessitating differential diagnosis in undifferentiated patients. It is recommended that in addition to HF findings (i.e. B-lines and pleural effusions), physicians evaluate other common pathologic features seen on LUS (i.e. consolidation or septations) together with clinical examination and laboratory analyses when examining patients for signs of HF [26]. These conditions often served as exclusion criteria in studies evaluating LUS in HF. (Table 2)

3.2. Diagnostic significance based on localization and standardizing the 8-Zone approach

The diagnostic significance of B-lines also depends on their anatomical localization. B-lines observed in the most lateral spaces (along the mid-axillary line) have diminished diagnostic utility in acute clinical settings, as noted in Buessler's 2020 study [27]. This limitation warrants careful consideration during diagnostic evaluations, especially in elderly patients where age-related changes in lung physiology or chronic lung disease may complicate interpretation. Cortellaro et al. demonstrated that LUS could detect a reduction in B-lines in patients with acute heart failure (AHF) within the first few hours of treatment after arrival in the emergency department. They evaluated eleven regions in the antero-lateral chest, estimating the B-line burden in each region. The B-line score was higher in the lower (more gravity-dependent) regions at baseline, and at 3 and 24 h after IV diuretic administration [28].

A potential solution to improve diagnostic accuracy may be to further standardize the 8-zone approach, that has recently been recommended by an EACVI position paper, by adjusting the scanning zones. Specifically, anterior scanning zones should be positioned closer to the sternum, while lateral zones should be placed along the anterior

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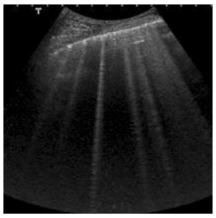
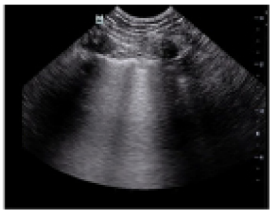
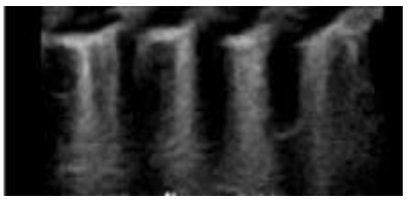
Table 2
Differential diagnosis for B-lines on lung ultrasound: Image examples.

Differential diagnosis		LUS Pattern
Acute and chronic heart failure		Hyperechoic vertical lines extending from the pleural line radiating to the edge of the ultrasound field (pleura line is not thickened)
Acute cardiogenic pulmonary oedema		Increased number of hyperechoic vertical lines extending from the pleural line radiating to the edge of the ultrasound field associated with pleural effusion (pleura line is not thickened)
ARDS		Multiple non-homogeneous B lines with a non-gravity-dependent distribution that may coexist with spared areas, pleural thickening with decreased or abolished lung sliding, and subpleural or translobar consolidations
Pulmonary consolidation (e.g. *pneumonia)*		Lung consolidation results from massive aeration loss. It appears as a tissue-like echotexture, with a superficial boundary at the pleural line and a deep irregular boundary with the aerated lung called the “shred sign”
Interstitial lung disease		Confluent b-lines with pleural line discontinuation

axillary line to minimize noise from the most lateral spaces [5].

3.3. Lack of standardized management algorithms

A major limitation in LUS is the lack of a globally recognized management algorithm based on imaging findings, enabling its consistent application across different clinical scenarios, including diagnosis and prognosis in patients with underlying comorbidities. Although a diagnostic framework for employing LUS in patients with suspected AHF in acute care has been proposed, the absence of a universally accepted HF management algorithm based on LUS findings remains a challenge [10]. There is a need for further research and consensus to fully leverage the diagnostic capabilities of LUS.

3.4. Variability in competence and technique

LUS research and utilization have increased dramatically over the last twenty years, with many physicians, mid-level providers, and nurses using LUS in various clinical settings and scenarios. Despite its utility in patients with known or suspected HF, some limitations are related to individual clinician competence, non-standardized imaging protocols, and the lack of practical patient management recommendations based on LUS findings [29]. B-lines can vary in length and distribution. Shorter (1–2 cm), vertical reverberation artifacts arising from the pleural line (‘comets’) may be difficult to differentiate from traditional B-lines, particularly in patients with acute distress syndrome where both peribronchial and interstitial edema occur simultaneously [30]. In such cases, chest radiography and chest tomography may support the diagnosis [31]. Ultimately, the competence of the reader is crucial in managing these challenging situations, highlighting the need for rigorous LUS training. Data on how the utility of LUS depends on the level of training and expertise are currently lacking, and such studies should be conducted to address this gap.

3.5. Impact of BMI and chest deformations

BMI and chest deformations can hinder a correct ultrasound examination. Higher BMI is associated with more thoracic subcutaneous adipose tissue and a greater distance between the probe and parenchymal lung. Similarly, severe skeletal distortion can make some lung areas

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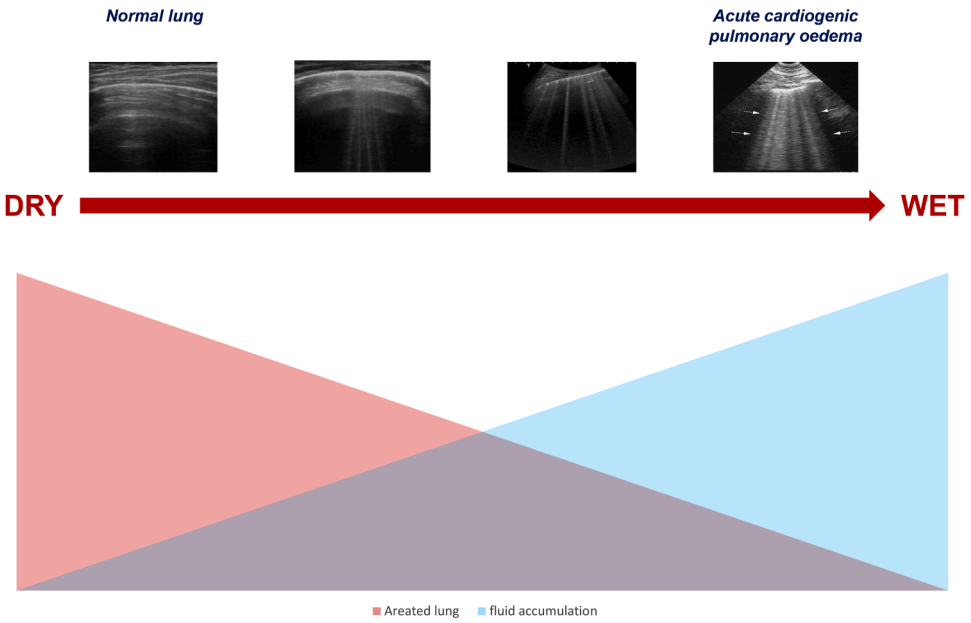

Fig. 4. B-line image examples in relationship to different degrees of pulmonary congestion.

difficult to image. For AHF, B-lines declined to a lesser degree than NT-proBNP with increasing BMI [32]. Brainin et al. demonstrated an inverse relationship between B-line number and chest wall thickness, varying by chest region. The number of B-lines decreased by 12 % per 5-unit increase in BMI (CI −19 % to −5 %, $P = 0.001$), whereas NT-proBNP concentration decreased by 28 % per 5-unit increase in BMI (CI −40 % to −16 %, $P < 0.001$). In chronic HF, B-line number decreased by 18 % per 5-unit increase in BMI (CI −35 % to +5 %, $P = 0.11$). Further studies are necessary to clarify if LUS is less likely to detect B-lines in very obese patients [33].

3.6. Uncertainties in heart failure management

Different imaging protocols and B-line quantification methods, together with different transducers and patient positioning during the examination, have produced results that make the establishment of unified B-line cut-off values difficult [7,9,34]. To address this issue, a recent EACVI position paper recommended the systematic utilization of an imaging protocol based on four zones for each thorax [5]. However, despite the use of LUS for monitoring congestion, standardized B-lines thresholds improving risk stratification beyond traditional tools (NP, CXR) are still lacking. The B-line thresholds for managing acute and chronic HF also warrant further research. In chronic HF, there is no evidence on how LUS could facilitate identifying a subset of patients who could benefit from specific interventions [35]. Although current ESC heart failure guidelines recommend the use of LUS among patients with suspected AHF, it is likely underused in ambulatory setting and stable patients. Data regarding how commonly LUS is used both in the acute setting as well as in chronic HF setting are sparse [36,37]. Consequently, the clinical and financial impact of the systematic application of LUS during ambulatory visits in patients with known or suspected HF is unclear and warrants further investigation. Finally, the utility of LUS in specific HF subtypes such as myocarditis, cardiotoxicity, hypertrophic, and infiltrative diseases has not been thoroughly assessed.

4. The role of LUS in different HF stages and phenotypes

Congestion is the most common physical sign of AHF usually manifested as isolated signs (pulmonary or peripheral congestion) or mixed congestion (central and peripheral). A subset of patients in apparently stable haemodynamic status have a subclinical congestion without peripheral edema or pulmonary rales; in these patients sonographic B-lines can detect subclinical pulmonary interstitial oedema [38]. Based on current assumptions fluid overload may occur in different body compartments due to a variety of mechanisms [39]. In addition, LUS may be particularly useful in those patients with grey zone NP levels (e.g. those with early HF decompensation, obesity, atrial fibrillation or renal dysfunction) that might confound the interpretation of the NP value. Under these conditions, the approach of using CXR/NP may not increase the accuracy of clinical evaluation alone and the introduction of a LUS-integrated assessment may improve the diagnostic accuracy.

Notably, another relevant diagnostic role of LUS is probably attributed to subclinical AHF in patients with chronic HF affected by recurrent decompensations, and in patients with initial symptoms but no prior HF diagnosis. In both conditions, the evidence of few B-lines during a LUS examination may reveal an early pulmonary congestion state facilitating timely diagnosis [40]. (Fig. 4) Moreover, the disappearance of B-lines following HF/decongestive therapy may confirm the HF-related aetiology of B-lines.

LUS integrated with echocardiography can facilitate a better knowledge and understanding be-tween haemodynamic and pulmonary congestion. In chronic HF, stress echocardiography can be complemented by LUS at rest and after exercise to assess the dynamic changes of B-lines [41]. Peak stress B-lines correlate with systolic pulmonary artery pressure, worse wall motion score index, weaker left ventricular contractile reserve and abnormal cardiac autonomic function mirrored by chronotropic incompetence [42,43]. Increased pulmonary congestion during stress is associated with greater functional impairment and worse outcomes among patients with exertional dyspnoea. Exercise LUS showed good diagnostic value for Heart Failure and preserved ejection fraction (HFpEF) diagnosis regardless of different exercise protocols, adding peak or change B-lines on top of HFpEF scores and natriuretic peptides significantly improved diagnostic accuracy [44].

Recent data demonstrated the utility of LUS in patients with severe aortic stenosis undergoing transcatheter aortic valve implantation (TAVI). LUS revealed a high prevalence of pulmonary con-gestion in patients with severe AS prior to TAVI, with a significant reduction in B-lines within days following the procedure [45].

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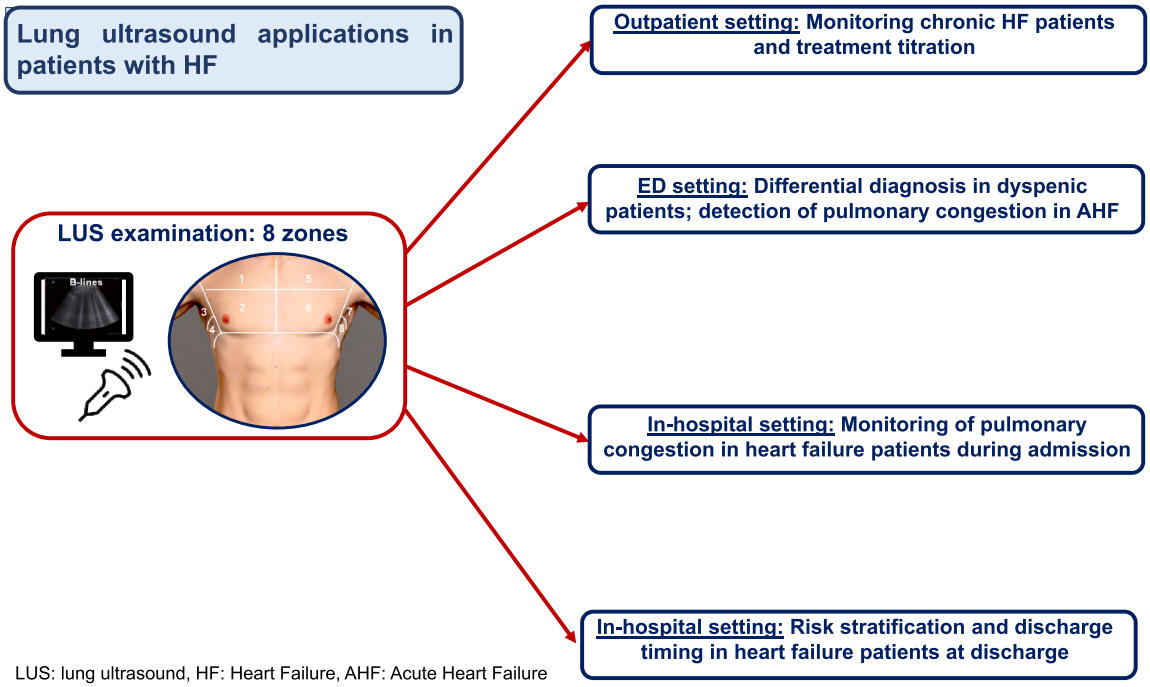
Lung ultrasound applications in patients with HF
LUS examination: 8 zones
B-lines
Outpatient setting: Monitoring chronic HF patients and treatment titration
ED setting: Differential diagnosis in dyspenic patients; detection of pulmonary congestion in AHF
In-hospital setting: Monitoring of pulmonary congestion in heart failure patients during admission
In-hospital setting: Risk stratification and discharge timing in heart failure patients at discharge
LUS: lung ultrasound, HF: Heart Failure, AHF: Acute Heart Failure

Fig. 5. Potential applications of LUS in different clinical scenarios ranging from ambulatory to hospitalized patients with heart failure.

5. How LUS can improve management and therapeutic decisions

With the continuously growing body of literature and clinical experience with LUS use, it is becoming a new tool for screening and diagnosis in various clinical contexts. Potential benefits and clinical application are reported below:

5.1. LUS in primary care

Early detection of pulmonary congestion and subsequent treatment of HF has the potential to reduce the number of hospitalizations, with implications for patients' quality of life and morbidity. In the general population, a particular diagnostic screening that includes a visit and a point-of-care LUS and echocardiogram could be used to make an early diagnosis. Indeed, due to the lack of specificity of the symptoms and the late occurrence of clinical congestion signs, diagnosing de novo HF in primary care (PC) remains difficult to ascertain. As a result, LUS can be an additional, easy, and rapid approach for identifying patients with a new diagnosis of HF. A recent study analysing LUS in primary care demonstrated that the evaluation of B-lines in anterior, lateral, and posterior locations can be used to appropriately rule in HF [46]. Combining LUS with NP's, given their negative predictive value, has the potential to shorten diagnosis and reduce treatment delays. Given that point-of-care NP testing is not always available in primary care clinics, LUS appears to be an alternative tool for clinicians, and its use could be expanded to be combined with NP assessment for initial screening and management of patients with suspected HF. Recently LUS has emerged as a valuable adjunct for diagnosing and predicting outcomes in HF and STEMI patients, even in those patients with subclinical congestion [47]. A new classification on top of Killip class using LUS method of $\geq$1 positive zone provides enhanced risk stratification compared to the Killip scale. A higher number of B-lines on admission was associated with an increased risk for developing symptomatic HF during the hospitalization, higher in-hospital mortality rate and adverse long term outcomes [48].

5.2. LUS in outpatients with chronic HF

Since congestion accounts for 90 % of HF recurrence the presence of pulmonary congestion may identify HF patients at high risk of HF hospitalization and death. As a result, lung congestion assessment enables better risk stratification in chronic HF patients and allows for more effective management of HF patient during follow-up. A report including 577 HF patients demonstrated the significance of B-line count as an independent predictive factor. Specifically, a higher number of B-lines identified patients with a 2.6-fold increased risk of death and re-hospitalization [49]. Thus, a strategy including LUS during routine outpatient visits may identify HF patients with high risk of congestion recurrence better than clinical evaluation alone, facilitating tailored HF treatment [49].

5.3. LUS monitoring to guide HF treatment

In HF patients, diuretics, play a crucial role in decreasing pulmonary congestion. Because B-lines on LUS reflect the dynamic changes in extravascular lung water, serial screening could be relevant in both acute and chronic HF patients, in particular those who are prone to recurrent rehospitalizations. The assessment and quantification of pulmonary congestion may help to guide treatment in HF patients. Rivas-Lasarte et al. conducted a randomized clinical trial comparing the use of LUS-guided HF management to usual care in patients following a recent hospitalization for AHF. Optimized diuretic titration associated with fewer subsequent de-compensations with LUS-guided treatment with a HR of 0.518 [95 % (CI) 0.268–0.998; $P = 0.04$], mainly related to fewer visits for worsening HF [50]. Similarly, in the CLUSTER-HF trial that randomized patients with a recent hospitalized for AHF to LUS-guided HF management vs. usual care, the incorporation of LUS into clinical follow-up lead to a 45 % reduction of risk (hazard ratio 0.55, 95 % CI 0.31–0.98, P = .04) of the primary endpoint (a composite of urgent HF visits, rehospitalization for worsening HF, and death from any cause), mainly driven by a reduction in urgent HF visits [51]. A systematic review and meta-analysis of several small randomized clinical trials suggests that outpatient LUS-guided diuretic therapy in patients with HF may reduce urgent visits for worsening symptoms of HF [52].

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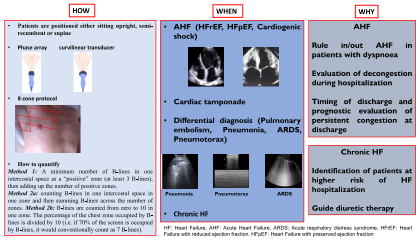

Central Figure: Overview of LUS method, clinical settings, and utility of LUS in clinical practice

The BLUSHED-AHF trial demonstrate that LUS to target pulmonary congestion in emergency department conferred no benefit compared with standard of care in reducing the number of B-lines at 6 h or in 30 days outcomes. However, patients in the LUS-guided group experienced faster resolution of congestion during the initial 48 h [53]. The role of LUS should be contextualized across a more complete ultrasound assessment. In addition to echocardiography, this may include inferior vena cava, jugular vein, and renal blood flow assessment to assess both pulmonary and systemic congestion prevalence and severity. Notably a holistic approach looking at lung cardiac and systemic congestion, may be much more informative on congestion status location and severity providing useful prognostic information [54].

In addition, serial LUS examinations during a hospitalization may potentially inform discharge timing and reduce readmissions. Notably, Gargani et al. in a single center study showed discharge B-lines number of <15 was associated with reduced risk of HF hospitalization [13]. Similarly, Palazzuoli et al. demonstrated that using 8 zones and a cut-off of >22 B-lines at discharge for HF with reduced ejection fraction (HFrEF) and 18 B-lines for HFpEF was associated with re-hospitalization for HF or death at 6 months [55]. Overall, the reduction of B-lines number from admission to discharge appears to be an important predictor, although different analyses revealed various cut-off values [56]. (Fig. 5) Future researcher may investigate target the exact percentage decrease in B-lines associated with both more appropriate time of discharge and improved post-discharge outcomes [57].

6. Conclusion

LUS is a non-invasive tool that provides several potential advantages in different clinical settings. The role and impact of pulmonary congestion detection by LUS compared to the traditional diagnostic assessment is still being investigated, however, several studies have demonstrated an additional diagnostic and prognostic value when standardized imaging protocols and B-line quantification methods are being used. Appropriate training on how to acquire and interpret LUS images within the clinical context is essential and can be accomplished through departmental implementation programs that include training. It will be important to address current gaps in evidence through multidisciplinary research efforts in order to optimize pulmonary congestion quantification and monitoring by using a standardized LUS protocols and scan time in patients with dyspnea and with known HF. Current applications may accelerate differential diagnosis and quickly recognize patients in need of specific HF management.

Declaration of competing interest

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